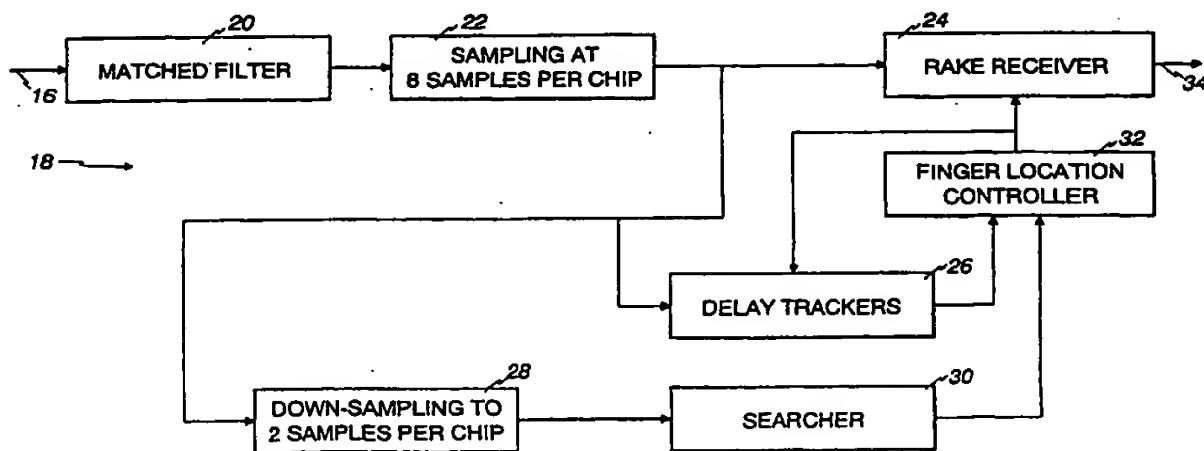


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(54) Title: DELAY SEARCHER AND DELAY TRACKERS INTERACTION FOR NEW DELAYS ASSIGNMENT TO RAKE FINGERS



(57) Abstract

A direct sequence spread spectrum receiver for operating in a multipath fading channel comprises a rake receiver having plural rake fingers. Each rake finger demodulates a received signal from one of plural channel paths. The output of the plural rake fingers are combined. Each rake finger utilizes a select assigned delay to synchronize to a delay of the one channel path. A searcher periodically performs a channel search on the received signal to detect new delays of strongest paths in the channel. Plural trackers, one for each channel path, adjust the select assigned delays between searches performed by the searcher. A delay controller is operatively coupled to the searcher and the tracker. The delay controller compares new delays of the strongest paths from the searcher to the select assigned delays and reassigns one of the select assigned delays with one of the new delays only if the new delay differs from the one select assigned delay more than a preselect minimum amount.

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## DELAY SEARCHER AND DELAY TRACKERS INTERACTION FOR NEW DELAYS ASSIGNMENT TO RAKE FINGERS

### FIELD OF THE INVENTION

This invention relates to direct sequence spread spectrum receivers and,  
5 more particularly, to interaction between delay searcher and delay trackers for new delay assignment to a rake receiver.

### BACKGROUND OF THE INVENTION

In a typical RF communication system, a transmitted signal may travel from a transmitter to a receiver over multiple paths, for example a direct path and also 10 a reflected path. Each path may be considered a separate channel which is subject to the effects of fading, dispersion, etc. Moreover, the combination of signals at the receiver can result in additional fading. Such operating environments are known as multipath fading environments. Direct sequence spread spectrum (DS-SS) receivers can operate in multipath fading environments. A DS-SS receiver typically includes a rake receiver, 15 which demodulates a received signal using plural demodulation "fingers", often referred to as rake fingers. Each rake finger demodulates the component signal from a number of the channel paths (such component signal referred to as a multipath component). The outputs of the rake fingers are combined for improved performance.

With multipath channels a transmitted signal arrives in components, with 20 each component having a different delay. The components can be distinguished and resolved if the delays are of sufficient duration. However, in order to demodulate the signals, the rake receiver must know the delay of each channel path.

Typically, a rake receiver operates in conjunction with a delay searcher and a delay tracker. The delay searcher analyzes a received signal and finds the delays. 25 These delays are assigned to the rake fingers. However, in mobile telecommunications the channels may be subject to additional fading due to the motion of the receiver. A delay tracker tracks the delays assigned by the searcher between channel searches. Thus,

while the searcher looks over a wide range of delays, the trackers look over a smaller range surrounding the assigned delays.

With such a configuration, problems may result during reassignment after a new search. One problem relates to loss of accuracy after the new search. Typically, a delay searcher uses less resolution than a delay tracker. When a new search is performed, the delay searcher may find a path with a delay that is close, but not exactly the same as that being tracked by the tracker. The path may actually be the same being tracked by the delay tracker. The difference in sensed delay is due to the lesser resolution of the delay searcher. Nevertheless, the delay searcher would assign the new delay to the rake finger, resulting in loss of accuracy until such time as the tracker subsequently adjusts the new delay.

Another problem relates to unnecessary relocation of rake finger delays. Typically, a delay searcher will assign a delay associated with the earliest arriving channel path to the first rake finger. Likewise, the next arriving channel path is assigned to the next rake finger, and so on. Due to fluctuation in relative signal strength of the changing channel paths, this can cause the same channel path to be reassigned to a different rake finger after subsequent searches. This reassignment takes time, and data may be lost during reassignment of the same channel path to a different rake finger.

The present invention is directed to overcoming one or more of the problems discussed above in a novel and simple manner.

#### SUMMARY OF THE INVENTION

In accordance with the invention there is disclosed an apparatus and method using delay searcher and delay tracker interaction for new delay assignment to a rake receiver.

Broadly, there is disclosed herein a direct sequence spread spectrum receiver for operating in a multipath fading environment comprising a rake receiver having plural rake fingers. Each rake finger demodulates a received signal component from one of plural channel paths (i.e., a multipath component). The outputs of the plural rake fingers are combined. Each rake finger utilizes a select assigned delay to

5 synchronize to a delay of the channel path to which it is assigned. A searcher periodically performs a channel search on the received signal to detect new delays of strongest paths in the channel. Plural trackers, one for each channel path, adjust the select assigned delays between searches performed by the searcher. A delay controller is operatively coupled to the searcher and the tracker. The delay controller compares new delays of the strongest paths from the searcher to the select assigned delays and reassigned one of the select assigned delays with one of the new delays only if the new delay differs from the one select assigned delay more than a preselect minimum amount.

10 It is a feature of the invention that the delay controller compares the detected delay of each of the strongest paths to each of the select assigned delays to determine nearest new delay to one of the select assigned delays. The delay controller determines if the determined nearest new delay is for the same path as the select assigned delay if the detected delay for the nearest new delay differs from the one select assigned delay less than the preselect minimum amount.

15 It is another feature of the invention that the delay controller reassigned the select assigned delays with a closest one of the detected new delays.

20 In accordance with another aspect of the invention, there is disclosed a direct sequence spread spectrum receiver for operating in a multipath fading channel including a rake receiver having plural rake fingers. Each rake finger demodulates a received signal from one of plural channel paths. The outputs of the plural rake fingers are combined. Each rake finger uses a select assigned delay to synchronize to a delay of the channel path to which it is assigned. A searcher periodically performs a channel search on the received signal to detect new delays of strongest paths in the channel. A delay controller is operatively coupled to the searcher. The delay controller compares new delays of the strongest paths from the searcher to the select assigned delays, and reassigned the select assigned delays with a closest one of the new delays.

25 In accordance with another aspect of the invention, there is disclosed a method of processing a received signal in a multipath fading channel comprising the steps of demodulating the received signal from each of plural channel paths utilizing a select assigned delay synchronized to a delay of one of the channel paths, periodically

performing a channel search to detect new delays of strongest paths in the channel, adjusting the select assigned delays between channel searches, and comparing new delays of the strongest paths to the select assigned delays and reassigning one of the select assigned delays with one of the new delays only if the new delay differs from the one select assigned delay more than a preselect minimum amount.

There is disclosed in accordance with yet a further aspect of the invention a method of processing a received signal in a multipath fading channel, comprising the steps of demodulating the received signal from each of plural channel paths utilizing a select assigned delay to synchronize to a delay of one of the channel paths, periodically performing a channel search to detect new delays of strongest paths in the channel, and comparing new delays of the strongest paths to the select assigned delays and reassigning the select assigned delays with a closest one of the new delays.

Further features and advantages of the invention will be readily apparent from the specification and from the drawing.

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#### BRIEF DESCRIPTION OF THE DRAWING

Fig. 1 is a block diagram of a direct sequence spread spectrum receiver in accordance with the invention;

Fig. 2 is a block diagram of the base band processor of Fig. 1; and

Fig. 3 is a flow diagram illustrating a flow chart implemented in the finger location controller block of Fig. 2.

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#### DETAILED DESCRIPTION OF THE INVENTION

Referring to Fig. 1, a direct sequence spread spectrum (DS-SS) receiver 10 according to the invention is illustrated. The receiver 10 operates in multipath fading channels and receives a transmitted RF signal via an antenna 12. The RF signal is down-converted from RF to baseband at a block 14 that provides a complex baseband signal on a line 16 to a baseband processor 18. Although a single antenna receiver is illustrated for simplicity, it will be appreciated that the present invention may be employed in a

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receiver having an array of antennas 12, and where an array of component signals is provided to the processor 18.

Referring to Fig. 2, the baseband processor 18 is illustrated in greater detail. The baseband signal on the line 16 is filtered using a matched filter 20, matched to the chip pulse waveform. This filter may be omitted if channelization filtering in the RF section 14 is sufficient. The filtered baseband signal is sampled to  $K$  samples per chip at a block 22. In one embodiment  $K$  is equal to eight. The sampled signal is applied to a rake receiver 24, a delay tracker 26, and a down-sampler 28. The down-sampler 28 down-samples the signal to  $L$  samples per chip which are then provided to a delay searcher 30, where  $L$  is some integer less than  $K$ . In one embodiment,  $L$  is equal to two. The delay trackers 26 and delay searcher 30 are in turn connected to a delay controller 32, which is in turn connected to the rake receiver 24 and the delay trackers 26.

The rake receiver 24 may be of any conventional construction comprising a number of demodulation fingers, which are also known as rake fingers. Each rake finger receives and demodulates the signal component from one of a number of channel paths, known as a multipath component. The outputs of the rake fingers are then combined to develop an output signal on a line 34 representing the original transmitted signal. For a rake finger to demodulate the signal from one channel path, the finger must be able to synchronize to a delay of the path. The delay of the path represents a time duration, represented in microseconds, samples or chips, relative to a time reference. The delays of the strongest paths in the channel are detected by the delay searcher 30. Particularly, the delay searcher 30 may be of conventional construction and periodically makes a channel search and finds the delays of new strong paths in the channel. An example of a sliding correlation searcher is disclosed in U.S. Patent Application No. 09/096,960, "Pilot Strength Measurement and Multipath Delay Searcher for CDMA Receiver", filed June 12, 1998, and owned by the assignee of the present application, the specification of which is incorporated by reference herein. With prior DS-SS receivers the new delays were directly assigned to the rake receiver 24 to replace previously assigned delays. The delay trackers 26 are also of conventional construction.

The delay trackers 26 fine tune the delay estimation of the delays assigned to the rake receiver 24. Each rake finger is associated with one tracker that updates and fine tunes the delay to the channel to which the finger is assigned between searches performed by the searcher 30.

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It will be understood that the delay associated with a multipath channel is the same as the delay associated with the multipath component received over the corresponding multipath channel. Thus, the terms "path delay" and "component delay" may be used interchangeably.

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In accordance with the invention, the particular delays assigned to the rake receiver 24 and fine tuned by the delay trackers 26 are determined by the finger location controller 32, rather than the searcher 30. The delay searcher 30 makes a periodic search over a wide range of channel delays, and it detects new channel path delays. Since the searcher 30 makes a search over a wide range of possible delays in the channel, to speed up the search process, and to simplify implementation, this search is performed with a reduced sampling rate, as indicated by the down-sampling to  $L$  samples per chip at the block 28. The reduced sampling rate causes the results of the delay searcher 30 to be less accurate. When the searcher 30 completes a new search, the delays that are used by the delay trackers 26 and the rake receiver 24 may be updated if stronger channel paths appear. In accordance with the invention, the delay controller 32 updates the delays being tracked and fine tuned by the trackers 26 with the delays detected by the searchers 30, such that the updating process does not cause performance degradation in the rake receiver 24.

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The baseband processor 18 may consist of a programmed microprocessor or controller performing the various functions illustrated in Fig. 2. A flow chart illustrating a program implementing the function of the delay controller 32 is illustrated in Fig. 3. In this implementation the finger location controller utilizes a matrix for assigning new delays to the rake receiver 24. The number of rake fingers in the rake receiver 24 may be fixed or variable. Typically, the number is variable and depends principally on the number of channel paths having sufficiently strong signals to be

detected. Thus, after each new channel search the number of paths found and delays assigned to the rake receiver 24 are variable.

The flow chart of Fig. 3 assumes that after any search the delay searcher 30 found  $M$  new channel paths at delays  $S(i)$ , where  $1 \leq i \leq M$ . The operation also assumes that prior to the completion of the search the delay trackers 26 were tracking  $N$  paths at delays  $T(j)$ , where  $1 \leq j \leq N$ . In a typical embodiment, the delays  $S(i)$  and  $T(j)$  are represented in units of samples where one sample =  $1/8$  chip period. The variables  $S(i)$  represent new detected delays found by the searcher 30. The variables  $T(j)$  represent the current delays being tracked and adjusted by the delay trackers 26.

Referring to Fig. 3, the  $M$  delays from the searcher 30 and the  $N$  delays from the delay tracker 26 are applied to a block 40, which forms an  $N$  row by  $M$  column controller matrix. Each element in the matrix is the absolute value of  $|S(i)-T(j)|$ . The following illustrates an example for  $M=4$  and  $N=3$ .

	$S(1)$	$S(2)$	$S(3)$	$S(4)$
$T(1)$	$ S(1)  -  T(1) $	$ S(2)  -  T(1) $	$ S(3)  -  T(1) $	$ S(4)  -  T(1) $
$T(2)$	$ S(1)  -  T(2) $	$ S(2)  -  T(2) $	$ S(3)  -  T(2) $	$ S(4)  -  T(2) $
$T(3)$	$ S(1)  -  T(3) $	$ S(2)  -  T(3) $	$ S(3)  -  T(3) $	$ S(4)  -  T(3) $

A variable  $m$  is initialized to zero at a block 42. A block 44 increments the variable  $m$  by one. A block 46 sets a variable  $z$  to be equal to the smallest element in the controller matrix formed at the block 40. The element  $z$  corresponds to the nearest new detected delay from the searcher 30 to a delay being tracked by one of the delay

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trackers 26. For example, if the element  $z$  is located at row number 2 and column number 3, this means that the third detected path by the searcher 30 and the second tracker path are the closest. At a block 48, a value  $r$  is set to the row number of the smallest element determined at the block 46 and a variable  $c$  is set to the column number of the smallest element in the controller matrix determined at the block 46. A block 50 then deletes all elements in row  $r$  and all elements in column  $c$  of the controller matrix formed at the block 40. The modified matrix becomes:

	$S(1)$	$S(2)$	$S(4)$
$T(1)$	$ S(1) $	$ S(2) $	$ S(4) $
$T(1)$		$T(1)$	$T(1)$
$T(3)$	$ S(1) $	$ S(2) $	$ S(4) $
$T(3)$		$T(3)$	$T(3)$

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As a result, if the second tracker is to be reassigned, it will be reassigned the third searcher delay. Deleting the elements at the block 50 prevents any more assignment to the second tracker or any more assignment of the third searcher new delay.

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A decision block 52 determines if the variable  $z$  is greater than a preset parameter  $\delta$ . The value  $\delta$  determines the resolution to be used. A typical value for  $\delta$  is on the order of 2, i.e., 0.25 chip periods. If  $z > \delta$ , then this indicates that the searcher detected path, path 3 in the example, is a new path with a considerably different delay than the corresponding tracker path, path 2 in the example. If so, then at a block 54 the delay of the tracker  $T(r)$  is set equal to the searcher  $S(c)$  delay. Conversely, if  $z$  is not greater than  $\delta$ , indicating that the third searcher detected path is the same path being tracked, then the delay  $T(r)$  is not changed and keeps its old value at a block 56. This new delay  $T(r)$  is also assigned to the corresponding rake finger.

From block 56 the control proceeds via a node A to a decision block 58 which determines if there are more elements remaining in the control matrix. If so, then control returns to the block 44. The process discussed above between the blocks 44 and the block 56 is then repeated until all elements in the controller matrix are deleted. If 5  $M=N$  or  $M < N$ , then the paths detected by the searcher are assigned to the rake receiver 24 and the delay trackers 26 and the process is completed. Otherwise, there are additional paths to be assigned to trackers, as described more particularly below.

If no more elements are found in the controller matrix at the decision block 58, then a decision block 60 determines if  $m=M$ . If so, then the process is 10 complete. However, in the event that the number of paths has decreased, i.e., if  $M < N$ , then there are  $N-M$  trackers that have not been confirmed with the original delay, nor are they assigned to new paths. These trackers and their corresponding rake fingers are thus turned off at a block 62 and the routine ends at a block 64. Conversely, if  $M > N$ , then 15 there are more new paths detected by the searcher 30 than the current number of paths being tracked by the trackers 26. This occurs if  $m$  is not equal to  $M$  at the block 60. In this case, the variable  $m$  is incremented at a block 66. A block 68 sets the column number  $c$  to any number from 1 to  $M$  which  $c$  has not been assigned previously at a block 68. The tracker  $T(m)$  is then assigned the delay  $S(c)$  at a block 70. A decision block 72 then determines if  $m$  equals  $M$ . If so, then control proceeds to the block 64 and 20 the routine ends. If not, then control returns to the block 66 to continue assigning the remaining searcher detected paths to the trackers 26 and the rake fingers.

Proceeding from block 52 to block 54 implies that the smallest element in the matrix exceeded the threshold  $\delta$ . Thus, all remaining elements will also exceed  $\delta$ , implying that the remaining searcher delays should be assigned to delay trackers.

It is apparent from the above description that the operation of the finger 25 location controller minimizes the problems of loss of accuracy and unnecessary relocation of trackers discussed above. The selection of the smallest elements in the controller matrix ensures that there is no unnecessary relocation of raker fingers. The comparison with  $\delta T_c$  before reassigning trackers makes sure that the trackers are 30 reassigned only when necessary. Particularly, this method identifies the pairs of searcher

and tracker delays that are closest in delay to each other, and assigns the searcher new detected delays to trackers only if they are due to a different channel path.

DS-SS receivers may be implemented without using delay trackers. Instead, the paths detected by the searcher are directly used by the rake finger without fine tuning. This is particularly done when the searcher hardware allows it to work with a large number of samples per chip. In such a receiver design, the loss of accuracy problem discussed above does not exist. Even when the searcher has good resolution (sufficient number of samples per chip), delay trackers may still be used, to allow delay estimates to be refined between searcher updates. Thus, the baseband processor 18 in accordance with the invention can still be used to eliminate the problem of unnecessary relocation of fingers.

While the present invention has been described with regards to a rake receiver employing a plurality of fingers, the invention can be used with other forms of rake reception. For example, the rake receiver can be implemented as a sliding correlator followed by a tapped delay line. The sliding correlator produces despread values corresponding to successive delay values. These despread values are then stored in the tapped delay line. A rake finger would correspond to a position on the tapped delay line, which would be tapped off for use in rake combining.

A key aspect of the present invention is that fingers assigned to existing channel paths are not reassigned, disrupting the demodulation process. This implies not only preserving the delay estimate from the delay tracker, but also preserving other demodulation information for that finger, such as a channel coefficient estimate and possibly automatic frequency correction (AFC) estimates. With traditional rake combining, the despread value is multiplied by the conjugate of the corresponding channel coefficient. Channel coefficients can be estimated using a pilot channel, pilot symbols, and/or decision feedback. Also, AFC estimates such as a frequency error estimate and/or phase estimate may be needed to account for local oscillator imperfections or a Doppler shift in the channel path. Channel estimation and AFC are discussed in more detail in pending U.S. Application No. 08/991,770, "Method and Apparatus for Frequency Acquisition and Tracking in DS-SS CDMA Receivers", filed

December 16, 1997, owned by the assignee of the present application, the specification of which is incorporated by reference herein. Thus, in Fig. 3, block 56, not only is the delay estimate preserved, but the other estimates associated with the finger are also preserved.

When fingers are reassigned, which occurs in block 54 of Fig. 3, channel and AFC estimates must be re-initialized. The simplest solution is to set the channel coefficient to zero and the AFC phase and frequency error estimates to zero. However, there will be a delay before these estimates become accurate, delaying the usefulness of the newly assigned finger. To reduce this delay, in accordance with the present invention, the estimates are initialized to nonzero values. For channel estimation, the channel coefficient is initialized to a first measured value, possibly scaled down to account for the measured value being noisy. For example, in a system with a pilot channel such as IS-95, the first correlation to the pilot channel can be used to initialize the channel coefficient.

For AFC, if present, the frequency error estimate can be initialized to an existing estimate from another finger, for example the strongest, or from some composite frequency error estimate based on multiple fingers. If AFC employs a phase-locked-loop, then the phase can be initialized to the phase of a first measured channel coefficient value. For example, in a system with a pilot channel such as IS-95, the phase of the first correlation to the pilot channel can be used to initialize the phase estimate. Thus, in general, demodulation information from a first set of channel paths (e.g., existing fingers) can be used to initialize demodulation from a second set of channel paths (e.g., new fingers). Each set may contain one or more elements.

Initialization of fingers also occurs when the receiver is first turned on. For this case, initialization based on the first, or a set of first measurements can also be used. For AFC, the frequency error estimate can be initialized to a value obtained from some initial coarse frequency error estimation or initialized to zero.

As will be appreciated by one of skill in the art, the present invention may be embodied as methods or devices. Accordingly, the present invention may take the

form of an entirely hardware embodiment, an entirely software embodiment, or an embodiment combining software and hardware aspects.

The present invention has been described in part with respect to Fig. 3, which is a flowchart illustration of an embodiment of the present invention. It will be understood that each block of the flowchart illustration, and combinations of blocks in the flowchart illustration, can be implemented by computer program instructions. These program instructions, which represent steps, may be provided to a processor to produce a machine.

Accordingly, blocks of the flowchart illustration support combination of means for performing the specified functions and combinations of steps for performing the specified functions. It will also be understood that each block of the flowchart illustrations, and combinations of blocks in the flowchart illustrations, can be implemented by special purpose hardware-based systems which perform the specified functions or steps, or combinations of special purpose hardware and computer instructions.

Thus, in accordance with the invention there is disclosed a direct sequence spread spectrum receiver that provides delay searcher and delay tracker interaction for new delay assignments to rake fingers.

## CLAIMS

## WE CLAIM:

1. A direct sequence spread spectrum receiver for operating in a multipath channel comprising:

5 a rake receiver for demodulating a received signal by combining despread values from a plurality of channel paths, utilizing select assigned delays to synchronize to the channel paths;

a searcher periodically performing a channel search on the received signal to detect new delays of paths in the channel;

10 plural trackers for adjusting the select assigned delays between searches performed by the searcher; and

15 a delay controller operatively coupled to the searcher and the tracker, the delay controller comparing new delays from the searcher to the select assigned delays and reassigning one of the select assigned delays with one of the new delays only if the new delay differs from the one select assigned delay more than a preselect minimum amount.

2. The direct sequence spread spectrum receiver of claim 1 wherein the delay controller compares each new delay to each of the select assigned delays to determine nearest new delay to one of the select assigned delays.

20 3. The direct sequence spread spectrum receiver of claim 2 wherein the delay controller determines that the determined nearest new delay is for the same path as the select assigned delay if the determined nearest new delay differs from the one select assigned delay less than the preselect minimum amount.

25 4. The direct sequence spread spectrum receiver of claim 1 wherein the delay controller reassigns the select assigned delays with a closest one of the detected new delays.

5. The direct sequence spread spectrum receiver of claim 1 wherein the rake receiver has plural rake fingers, each assigned to one of the plurality of channel paths, each rake finger utilizing one of the select assigned delays to synchronize to a delay of the one channel path.

5 6. The direct sequence spread spectrum receiver of claim 1 wherein the delay controller initializes demodulation information corresponding to new delays.

7. The direct sequence spread spectrum receiver of claim 6 wherein initialization is based on a channel coefficient measurement corresponding to a new delay.

10 8. The direct sequence spread spectrum receiver of claim 6 wherein initialization is based on existing estimates.

9. A direct sequence spread spectrum receiver for operating in a multipath channel comprising:

15 a rake receiver for demodulating a received signal by combining despread values from a plurality of channel paths, utilizing select assigned delays to synchronize to the channel paths;

a searcher periodically performing a channel search on the received signal to detect new delays of paths in the channel;

20 plural trackers for adjusting the select assigned delays between searches performed by the searcher; and

a delay controller operatively coupled to the searcher and the tracker, the delay controller comparing new delays from the searcher to the select assigned delays and not reassigning any select assigned delay with one of the new delays unless each new delay differs from the select assigned delay more than a preselect minimum amount.

10. The direct sequence spread spectrum receiver of claim 9 wherein the delay controller compares each new delay of each path to each of the select assigned delays to determine nearest new delay to one of the select assigned delays.

5 11. The direct sequence spread spectrum receiver of claim 10 wherein the delay controller determines that the determined nearest new delay is for the same path as the select assigned delay if the determined nearest new delay differs from the one select assigned delay less than the preselect minimum amount.

10 12. The direct sequence spread spectrum receiver of claim 9 wherein the delay controller reassigned the select assigned delays with a closest one of the detected new delays.

15 13. The direct sequence spread spectrum receiver of claim 9 wherein the rake receiver has plural rake fingers, each assigned to one of the plurality of channel paths, each rake finger utilizing one of the select assigned delays to synchronize to a delay of the one channel path.

14. A direct sequence spread spectrum receiver for operating in a multipath channel comprising:

a rake receiver for demodulating a received signal by combining despread values from a plurality of channel paths, utilizing select assigned delays to synchronize to the channel paths;

20 a searcher periodically performing a channel search on the received signal to detect new delays of strongest paths in the channel; and

a delay controller operatively coupled to the searcher, the delay controller comparing new delays of the strongest paths from the searcher to the select assigned delays and reassigning the select assigned delays with the closest one of the new delays.

15. The direct sequence spread spectrum receiver of claim 14 further comprising plural trackers, one for each channel path, for adjusting the select assigned delays between searches performed by the searcher.

5 16. The direct sequence spread spectrum receiver of claim 15 wherein the delay controller determines that the determined nearest new delay is for the same path as the select assigned delay if the determined nearest new delay differs from the one select assigned delay less than a preselect minimum amount.

10 17. The direct sequence spread spectrum receiver of claim 14 wherein the rake receiver has plural rake fingers, each assigned to one of the plurality of channel paths, each rake finger utilizing one of the select assigned delays to synchronize to a delay of the one channel path.

18. The receiver of claim 14 wherein the delay controller initializes demodulation information corresponding to new delays.

15 19. The receiver of claim 18 wherein initialization is based on a channel coefficient measurement corresponding to a new delay.

20. The receiver of claim 18 wherein initialization is based on existing estimates.

21. A direct sequence spread spectrum receiver for operating in a multipath channel comprising:

a rake receiver for demodulating a received signal by combining despread values from a plurality of channel paths, utilizing assigned delays to synchronize to the channel paths;

a searcher periodically performing a channel search on the received signal to detect new delays of strongest paths in the channel;

plural trackers, one for each channel path, for adjusting the select assigned delays between searches performed by the searcher; and

10 a delay controller operatively coupled to the searcher and the tracker, the delay controller analyzing new delays of the strongest paths from the searcher and the adjusted select assigned delays and reassigning select assigned delays to the plural rake fingers responsive to receiving new delays from the searcher.

22. A method of processing a received signal in a multipath fading channel, comprising the steps of:

15 demodulating the received signal from each of plural channel paths utilizing a select assigned delay to synchronize to a delay of one of the channel paths;

periodically performing a channel search to detect new delays in the channel;

20 adjusting the select assigned delays between channel searches; and comparing new delays to the select assigned delays and reassigning one of the select assigned delays with one of the new delays only if the new delay differs from the one select assigned delay more than a preselect minimum amount.

25 23. The method of claim 22 wherein the comparing step includes the step of comparing each new delay to each of the select assigned delays to determine nearest new delay to one of the select assigned delays.

24. The method of claim 23 wherein the comparing step comprises the step of determining that the determined nearest new delay is for the same path as the select assigned delay if the determined nearest new delay differs from the one select assigned delay less than a preselect minimum amount.

5 25. The method of claim 22 wherein the comparing step reassigns the select assigned delays with a closest one of the detected new delays.

26. The method of claim 22 wherein the step of comparing includes initializing demodulation information corresponding to new delays.

10 27. The method of claim 26 wherein initialization is based on a channel coefficient measurement corresponding to a new delay.

28. The method of claim 26 wherein initialization is based on existing estimates.

29. A method of processing a received signal in a multipath fading channel, comprising the steps of:

15 demodulating the received signal from each of plural channel paths utilizing a select assigned delay to synchronize to a delay of one of the channel paths; periodically performing a channel search to detect new delays in the channel; and

20 comparing new delays to the select assigned delays and reassigning the select assigned delays with a closest one of the new delays.

30. The method of claim 29 further comprising the step of adjusting the select assigned delays between channel searches.

31. The method of claim 30 wherein the comparing step comprises the step of determining that the determined nearest new delay is for the same path as the select assigned delay if the determined nearest new delay differs from the one select assigned delay less than a preselect minimum amount.

5 32. The method of claim 29 wherein the comparing step reassigns the select assigned delays with a closest one of the new delays only if the closest one of the new delays differs from the one select assigned delay more than a preselect minimum amount.

10 33. The method of claim 29 wherein the step of comparing includes initializing demodulation information corresponding to new delays.

34. The method of claim 33 wherein initialization is based on a channel coefficient measurement corresponding to a new delay.

35. The method of claim 33 wherein initialization is based on existing estimates.

15 36. A method for initializing demodulation information corresponding to a channel path comprising the steps of:  
making at least one initial channel coefficient measurement; and  
initializing demodulation information using the at least one initial channel coefficient measurement.

20 37. The method of claim 36 wherein the demodulation information includes channel coefficient information.

38. The method of claim 36 wherein the demodulation information includes automatic frequency control information.

39. A method for initializing demodulation information corresponding to a channel path comprising the steps of:

storing demodulation information from a first set of at least one channel path; and

5 initializing demodulation information corresponding to a second set of at least one channel path using the stored information from the first set of at least one channel path.

40. The method of claim 39 wherein the demodulation information includes automatic frequency control information.

Fig. 1

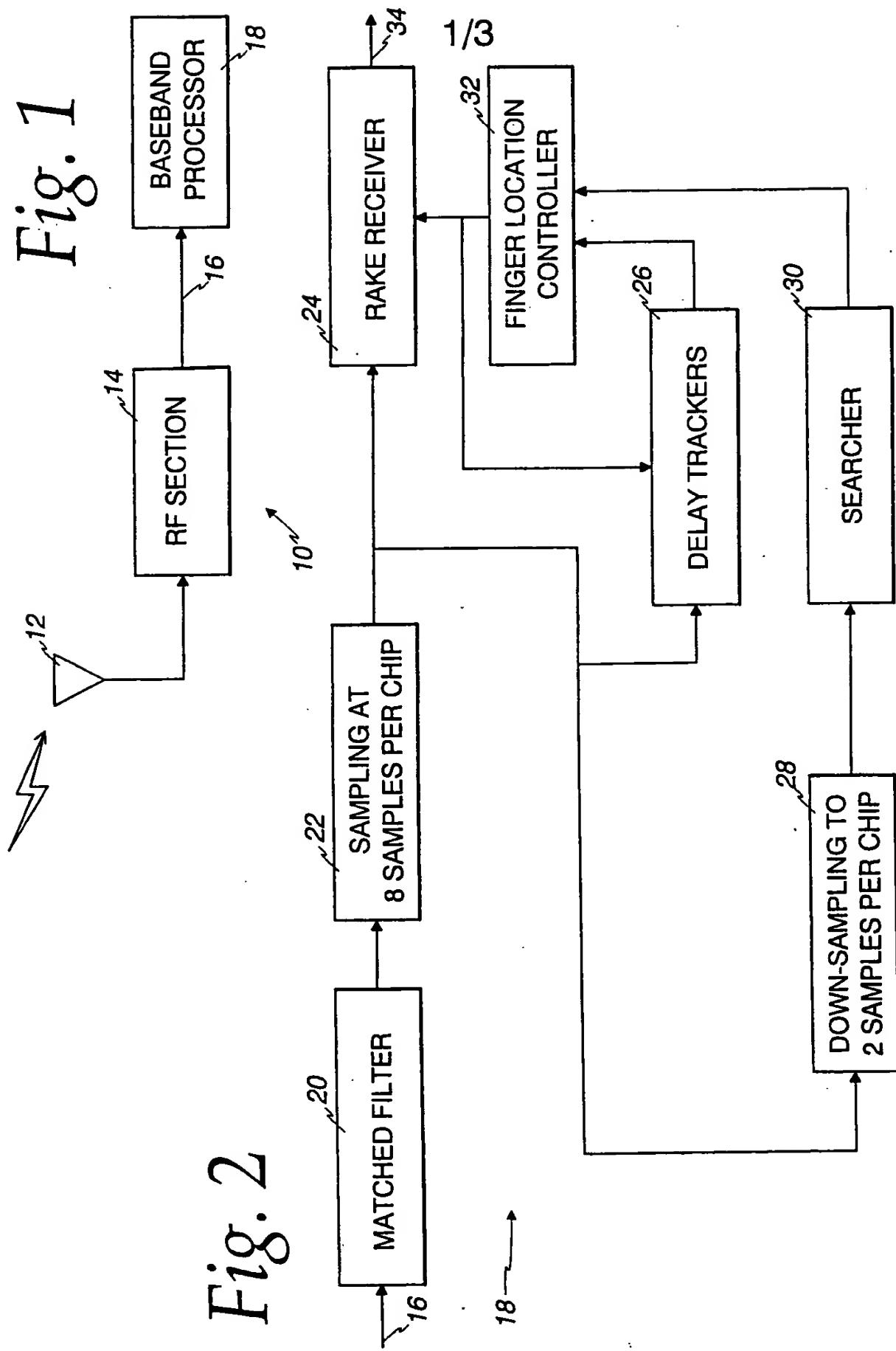


Fig. 2

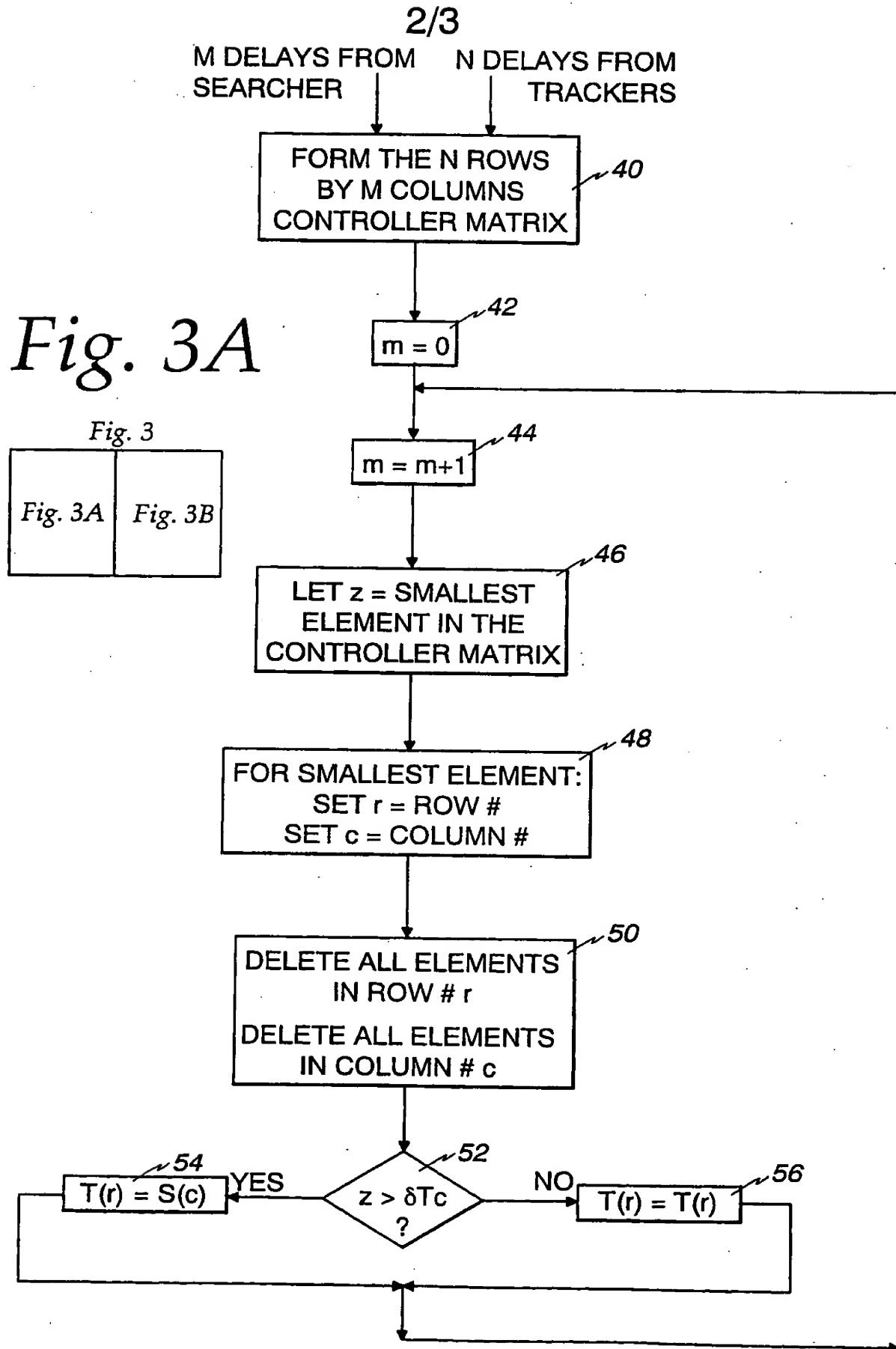
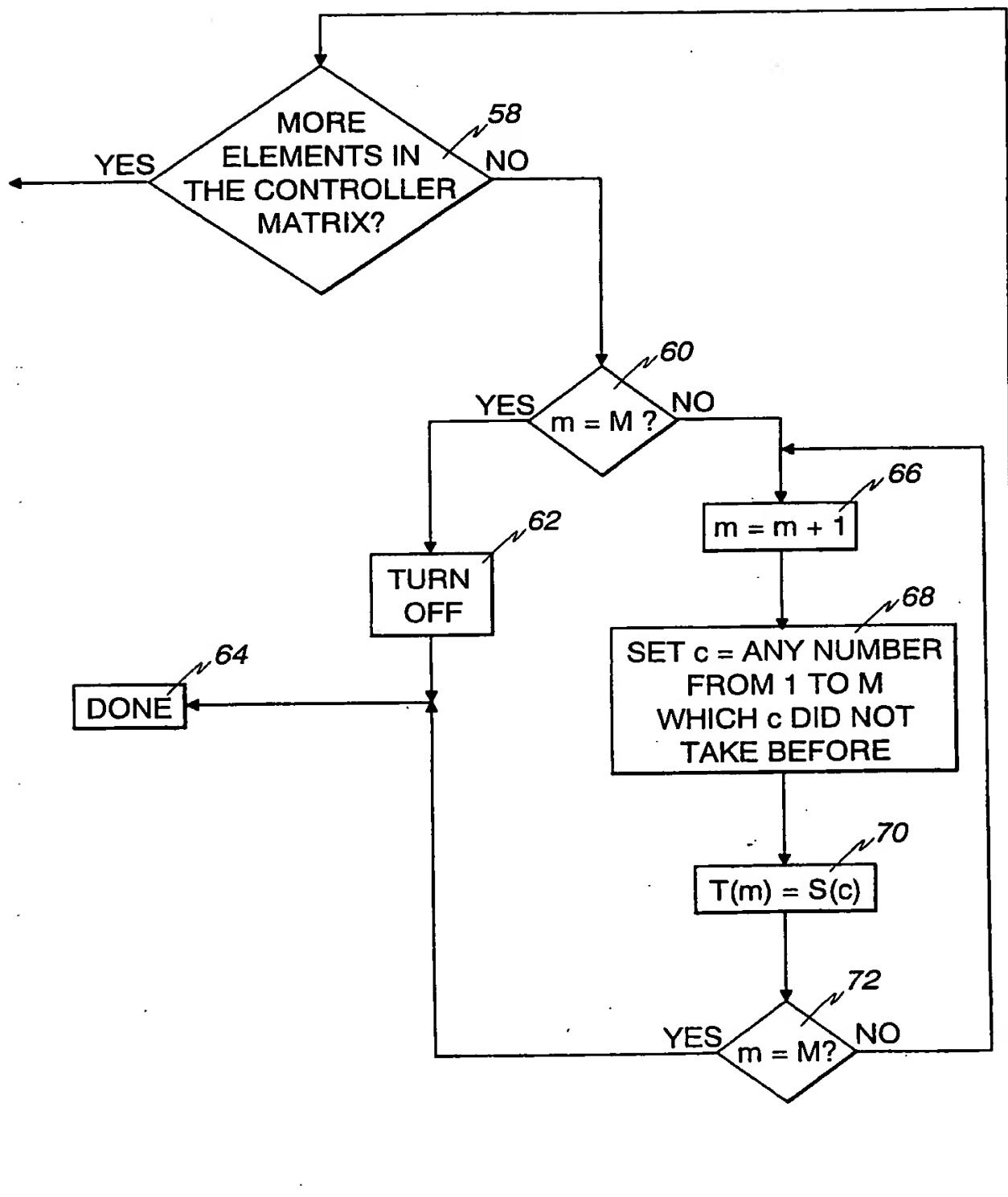
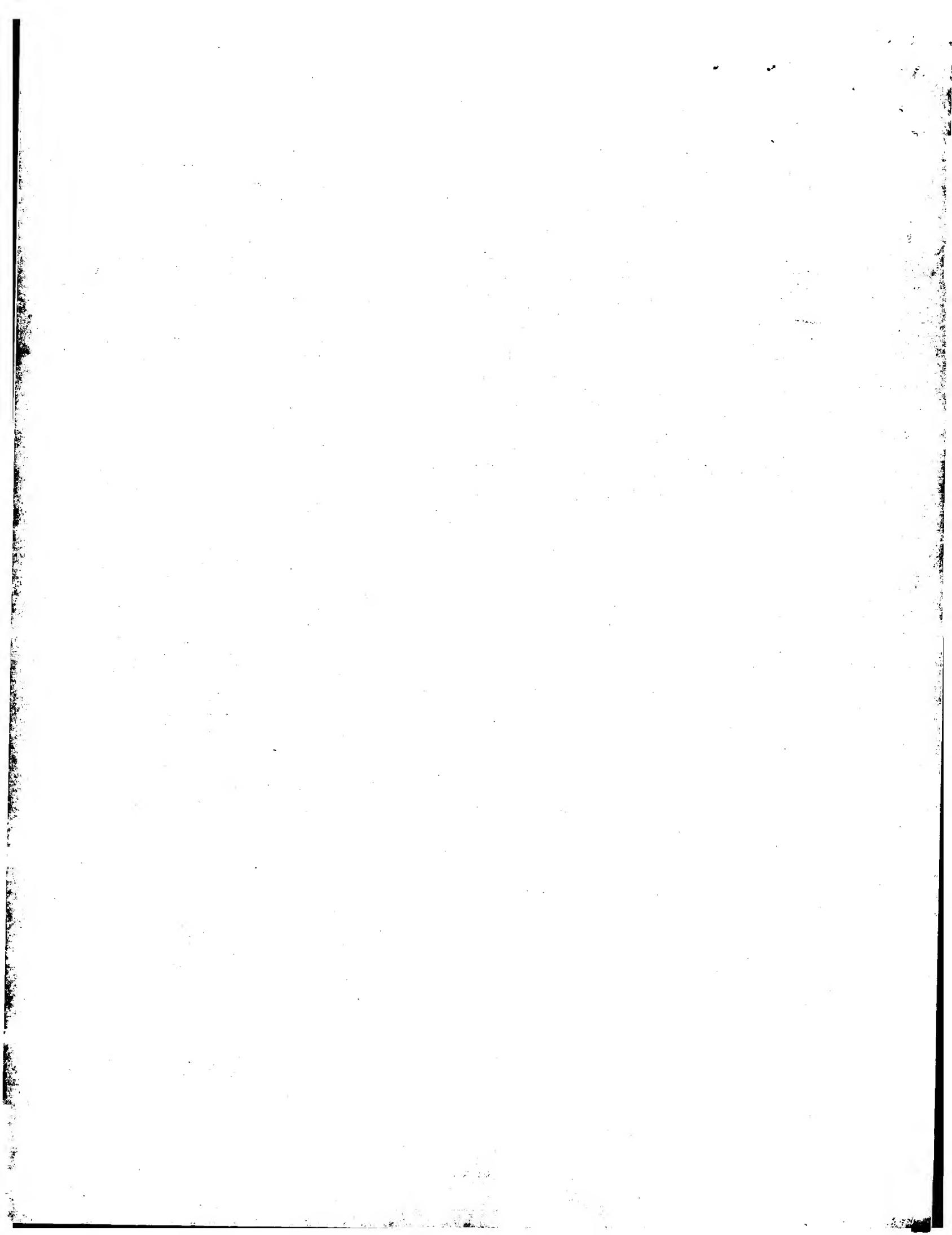


Fig. 3B

3/3



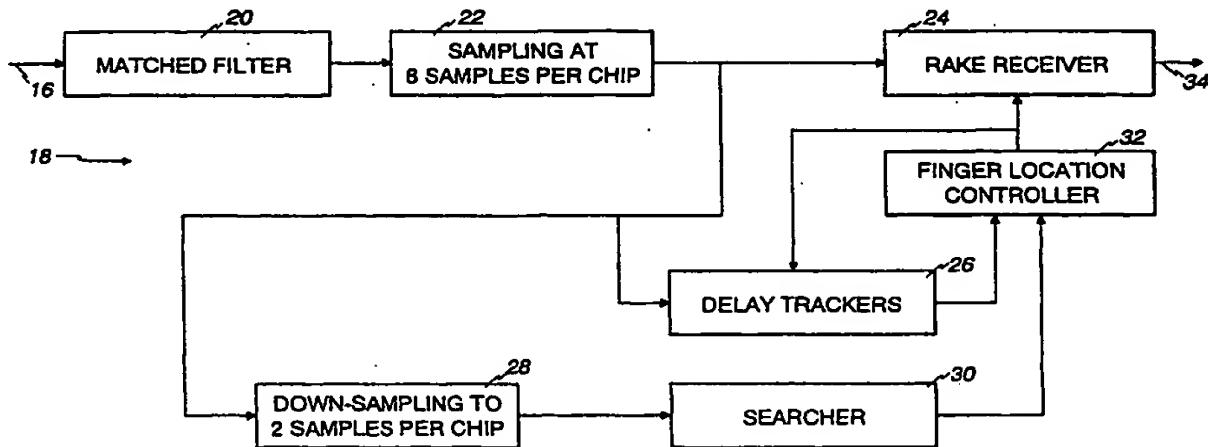


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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>7</sup> : <b>H04B 1/707, H04L 25/02</b>	A3	(11) International Publication Number: <b>WO 00/21201</b> (43) International Publication Date: <b>13 April 2000 (13.04.00)</b>
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(74) Agent: MONCO, Dean, A.; Wood, Phillips, VanSanten, Clark & Mortimer, Suite 3800, 500 West Madison Street, Chicago, IL 60661-2511 (US).		
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(54) Title: DELAY SEARCHER AND DELAY TRACKERS INTERACTION FOR NEW DELAYS ASSIGNMENT TO RAKE FINGERS



## (57) Abstract

A direct sequence spread spectrum receiver for operating in a multipath fading channel comprises a rake receiver having plural rake fingers. Each rake finger demodulates a received signal from one of plural channel paths. The output of the plural rake fingers are combined. Each rake finger utilizes a select assigned delay to synchronize to a delay of the one channel path. A searcher periodically performs a channel search on the received signal to detect new delays of strongest paths in the channel. Plural trackers, one for each channel path, adjust the select assigned delays between searches performed by the searcher. A delay controller is operatively coupled to the searcher and the tracker. The delay controller compares new delays of the strongest paths from the searcher to the select assigned delays and reassigns one of the select assigned delays with one of the new delays only if the new delay differs from the one select assigned delay more than a preselect minimum amount.

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# INTERNATIONAL SEARCH REPORT

Int'l Application No  
PCT/US 99/22437

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 H04B1/707 H04L25/02

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 H04B H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	<p>EP 0 896 438 A (LUCENT TECHNOLOGIES INC) 10 February 1999 (1999-02-10)</p> <p>abstract            column 2, line 21 – line 46            column 4, line 56 – column 5, line 23            column 8, line 2 – line 21; figure 5</p> <hr/> <p style="text-align: center;">-/—</p>	1,2,5, 14,15, 17, 21–23, 29–32

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

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Date of the actual completion of the international search

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**INTERNATIONAL SEARCH REPORT**

Inte	lational Application No
PCT/US 99/22437	

C(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	abstract; claims 1-3	17, 29
A	column 4, line 24 -column 5, line 30; figures 2,6	18, 20, 33, 35
	column 10, line 10 - line 43; figure 8	1-5, 9-13, 21-25, 30-32
X	WO 95 12262 A (QUALCOMM INC) 4 May 1995 (1995-05-04)	14, 15,
Y	page 1, line 15 - line 31	29, 30
A	page 7, line 29 -page 9, line 14	18-20, 33, 35
	page 28, line 29 -page 29, line 11; figures 8,9A-9D	1-5, 9-13, 16, 21-25, 31
	page 30, line 17 - line 25	
X	WO 97 19522 A (NOKIA TELECOMMUNICATIONS OY ;STAHLA LAURI (FI)) 29 May 1997 (1997-05-29)	36, 37, 39
Y	page 9, line 17 -page 11, line 9; claims 1,7,9,13; figures 2,3	18-20, 33-35
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A	column 2, line 43 - line 64 column 11, line 26 - line 62	37

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US 99/22437

### Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1.  Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:
  
2.  Claims Nos.: because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
  
3.  Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

### Box II Observations where unity of Invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this International application, as follows:

see additional sheet

1.  As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
  
2.  As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
  
3.  As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
  
4.  No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

The additional search fees were accompanied by the applicant's protest.

No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 1-8,21-28

A direct sequence spread spectrum receiver with RAKE demodulation, a searcher, trackers and a controller to detect whether or not the delays found by the searcher should be re-assigned to the ones tracked by the trackers. The controller further detects if one of the searcher delays differs from an already tracked delay more than a preselected minimum amount.

2. Claims: 9-13

A direct sequence spread spectrum receiver and method with RAKE demodulation, a searcher, trackers and a controller to detect whether or not the delays found by the searcher should be re-assigned to the ones tracked by the trackers. The controller further detects if each of the searcher delays differs from an already tracked delay more than a preselected minimum amount (which excludes the reassignment according to group 1).

3. Claims: 14-20,29-35

A direct sequence spread spectrum receiver with RAKE demodulation, a searcher, trackers and a controller to detect whether or not the delays found by the searcher should be re-assigned to the ones tracked by the trackers. The controller further re-assigns the delays already being tracked with the closest one of the delays found by the searcher.

4. Claims: 36-40

A method for initialising demodulation information of a channel path by making and using channel measurements or using storing automatic frequency control information from a set containing one or more paths and initialising demodulation information of a second set containing one or more paths using stored information from the first set of paths.

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

Int'l Application No  
**PCT/US 99/22437**

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